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JOURNAL

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ELISHA MITCHELL SCIENTIFIC SOCIETY

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THE FOUNDATIONS OF GEOMETRY.

BY ARCHIBALD HENDERSON, PH.D.

The study of the historical development of mathematics, and in particular the study of geometry, leads one to the conclusion that the great roles in the drama of science have been played by two inter-related, yet widely differing, forces—intuition and logic. Huxley once laughingly said of Herbert Spencer that his idea of tragedy was a deduction killed by a fact. Some of the greatest parts in the drama of science have been played by intuition; but that drama becomes a tragedy when intuitional prevision is annihilated by the inexorable irony of fact. The most epoch-making discoveries find their origin in the fortunate conjunction of intuition and experience. And the whole history of science is the history of the struggle of man's intuition, fortified by experience, to read the inscrutable riddle of Nature.

I venture to assert that nowhere is this struggle more succinctly and definitively illustrated than in the story of man's effort to formulate the hypotheses which constitute the foun-

Printed May 13.

dations of geometry. For precise reasons, the names of Euclid and Newton stand above all other names in the *fasti* of mathematics; and the reasons are strikingly similar in the two cases. In writing of *The Wonderful Century*, the nineteenth, Alfred Russel Wallace says of all time before the seventeenth century: "Then, going backward, we can find nothing of the first rank except Euclid's wonderful system of geometry, perhaps the most remarkable mental product of the earliest civilizations." In modern times, Newton's colossal figure occupies the centre of the stage, looming large, as he himself explained, because he stood upon the shoulders of giants. Like Euclid, his claim to pre-eminence rests less upon the discovery of new principles than upon the immeasurably greater service of the universal formulation and grounding of mathematics. Newton brought all natural phenomena under the reign of universal law, Euclid reduced all geometrical knowledge to system.

"It is certain," says Philip Kelland, "that from its completeness, uniformity and faultlessness, from its arrangement and progressive character, and from the universal adoption of the completest and best line of argument, Euclid's *Elements* stand pre-eminently at the head of all human productions. In no science, in no department of knowledge, has anything appeared like this work: for upwards of 2,000 years it has commanded the admiration of mankind, and that period has suggested little toward its improvement." Indeed it is no cranky enthusiasm, but absolute conviction that prompts the mathematician to say that geometry is ultimately fundamental for the progress of science and thea dvancement of humanity. It is continually bringing to pass those epoch-making events in the history of science whereby what one day seems to be the purest science becomes the next a vitally important piece of applied science. Such events enable us to realize that pure science and utilitarian science are not differentiable, butat bottom and in essence one and the same thing. "I often find the conviction forced upon me," said the brilliant English

geometer H. J. S. Smith, "that the increase of mathematical knowledge is a necessary condition for the advancement of science, and, if so, a no less necessary condition for the improvement of mankind. I could not augur well for the enduring intellectual strength of any nation of men, whose education was not based on a solid foundation of mathematical learning, and whose scientific conceptions, or, in other words, whose notions of the world and of the things in it, were not bound and girt together with a strong framework of mathematical reasoning."

In that charming book, cast in the dialogue form and entitled *Euclid and his Modern Rivals*, by the Rev. Charles L. Dodgson, the brilliant "Lewis Carroll" of *Alice in Wonderland* fame, Euclid confesses with reluctance that some secret flaw lies at the root of the subject of parallel lines. Probabilities, not certainties, are all that he has in vindication of his belief. Here we lay our fingers on the rift in the lute; in this confession, we catch a glimpse of that *ignis fatuus* that mathematicians have pursued in vain for well-nigh two thousand years. Professor G. B. Halsted cites Sohncke* as saying that in mathematics there is nothing over which so much has been spoken, written, and striven, as over the theory of parallels, and all, so far (up to his time), without reaching a definite result and decision. It is impossible, says the great Poincaré, to imagine the vast effort wasted in this chimeric hope, this evanescent dream. Indeed, it was not until the nineteenth century that the truth began to dawn upon the minds of men; and almost simultaneously from the distant frontiers of Europe, at Kazan on the Volga and at Maros-Vasarhely in far Erdély, there came the startling generalizations that have tended to revolutionize our conceptions of geometry, and thrown doubts upon the very nature of the space in which we live.†

Encyclopædie der Wissenchaften und Kunste; Von Ersch und Gruber, Leipzig, 1838, under "Parallel."

†Compare *The Value of Non-Euclidian Geometry*, by G. B. Halsted; Pop. Sci. Monthly, vol. 67, pp. 639-646. At the outset, I wish to acknow-

In order to make the matter clear to "the man in the street," it is necessary to speak, not so much as a mathematician as one who knows, let us say, no more of mathematics than is taught in the Freshman year in the college or university. We recall that Euclid uses three terms in laying the foundations for his geometry: *Definitions* (ὅροι), *Postulates* (αιτιήματα), and *Common Notions* (κοιναι εννοιαι). He defined his elements: point, line, etc.; he assumed that you can draw a straight line from one point to another; and he laid down as accepted such statements as "Things equal to the same thing are equal to each other," etc. For Euclid's *Common Notions* later geometers substituted the unfortunate term—unfortunate, as we shall subsequently see—*Axioms*. This word Axiom (Greek, αξιωμα) is used by Aristotle to mean "a truth so obvious as to be in no need of proof"—virtually in the modern sense of a "self-evident truth." Euclid used only five Postulates and thirteen Common Notions, none of which challenged doubt save the celebrated "parallel-postulate." Indeed, all were very simple except this fifth postulate,* which excited suspicion, not only on account of its cumbrous form, but because it is used only once—to prove the inverse of a proposition already demonstrated—the seventeenth. "It requires," says Staeckel, "a certain amount of courage to declare such a requirement, alongside the other simple axioms and postulates." The Swiss mathematician, J. H. Lambert,† averred that Proklos, Euclid's first commentator (410–485 A. D.) argued that the parallel-postulate was demonstrable, because it was the inverse of the seventeenth proposition. Euclid's twenty-seventh proposition: that straight lines

ledge my general indebtedness to the writings of Professor Halsted, to which I occasionally refer.

*Also given in various editions of Euclid as a Common Notion—eleventh, twelfth, or thirteenth.

†Lambert's *Theory of the Parallel Lines* was not published until 1786 twenty years after it was written and nine years after his death, by Bernouilli and Hindenberg in the *Magazin fur die reine und angewandte Mathematik*.

making with a transversal equal alternate angles are parallel, is easily demonstrated. But in order to prove its inverse: that parallels cut by a transversal make equal alternate angles, he is forced to resort to the following postulate axiomatically stated (Williamson's translation, Oxford, 1781):

11. *And if a straight line meeting two straight lines makes those angles which are inward and upon the same side of it less than two right angles, the two straight lines being produced indefinitely will meet each other on that side upon which the angles are less than two right angles* (*Fig. 1, Angle A + Angle B less than 180°*).

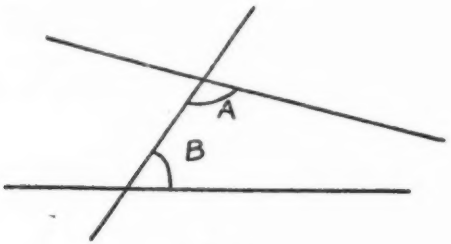


FIG 1.

The points to be observed in connection with this postulate are two in number. First, "no one had a doubt of the external reality and exact applicability of the postulate. The Euclidian geometry was supposed to be the only possible form of space-science, that is, the space analyzed in Euclid's axioms and postulates was supposed to be the only non-contradictory sort of space." Second, the postulate was neither so axiomatic nor so simple as the proposition it was used to prove; and hence the world of mathematicians concluded, with Proklos, that this postulate could be deduced as a theorem from the other assumptions and the twenty-eight preceding theorems. And so, for hundreds and hundreds of years, the

mathematical world exhausted itself in the effort to prove Euclid's celebrated parallel-postulate. Ptolemy, the great astronomer, wrote a treatise purporting to prove it; and Nasir Eddin (1201-1274), whose work on Euclid in Arabic was printed at Rome in 1594, sought to dispense with the problem of parallelism, by taking his stand upon another postulate: that two straight lines which cut a third straight line, the one at right angles, the other at some other angle, will converge on the side where the angle is acute, and diverge where it is obtuse. Other mathematicians, notably John Wallis whom I claim as an ancestor, sought to turn the flank of the difficulty by identifying the problem of parallels with the problem of similitude. In general, we may say that the problem was attacked from three sides.

First, there were those who sought to substitute a new definition of parallels for Euclid's, which reads (I, Def. 35):

> "*Parallel straight lines are such as are in the same plane, and which being produced ever so far both ways do not meet.*"

To cite a few classic definitions, Wolf, Boscovich, and T. Simpson use the following: "Straight lines are parallel which preserve the same distance from each other." But this is begging the question, asHalsted has remarked, since it assumes a *definition*, viz.: "Two straight lines are parallel when there are two points of the one on the same side of the other from which the perpendiculars to it are equal;" and at the same time assumes a *theorem:* "All perpendiculars from one of these lines to the other are equal." Those geometers who assume that parallel lines have the same direction are guilty of a *petitio principii*, in assuming (Varignon and Bezout) the *definition* that "parallel lines are those that make equal angles with a third line," and also in assuming the *theorem* that "Straight lines that make equal angles with one transversal make equal angles with all transversals."

The second method of attack, far more logical, was to pro-

pose a substitute for the parallel-postulate, such as "Two straight lines which intersect cannot *both* be parallel to the same straight line" (Ludlam), and "Any three points are collinear or concyclic" (Bolyai). And the celebrated Hilbert, in his *Vorlesung ueber Enklidische Geometric*, (winter semester, 1898-9) cites the following theorems:

1. The sum of the angles of a triangle is always equal to two right angles.
2. If two parallels are cut by a third straight line, then the opposite (corresponding) angles are equal.
3. Two straight lines, which are parallel to a third, are parallel to each other.
4. Through every point within an angle less than a straight angle, one can always draw straight lines which cut both sides (not perhaps their prolongations).
5. All points of a straight line have from a parallel the same distance.

His comment is, "Finally we remark, that it seems as if each of these five theorems could serve precisely as the *equivalent of the Parallel Axiom.*"

The third class of investigators consisted of those geometers who foundered upon the rock of the attempt to deduce Euclid's parallel-postulate from reasonings about the nature of the straight line and the plane angle, helped out by Enclid's other assumptions and his first twenty-eight theorems. Euclid took pains to prove things which were more axiomatic by far—for instance, that the sum of two sides of a triangle is greater than the third side—a thing which any ass knows. To give one illustration of the many so-called proofs, take the most plausible one, exposed by Charles L. Dodgson, in his *Curiosa Mathematica*, Part I. pp. 70-71, 3rd edition, 1890:

"Yet another process has been invented—quite fascinating in its brevity and its elegance—which, though involving the

same fallacy as the Direction-Theory, proves Euc. I, 32. without even mentioning the dangerous word 'Direction'.

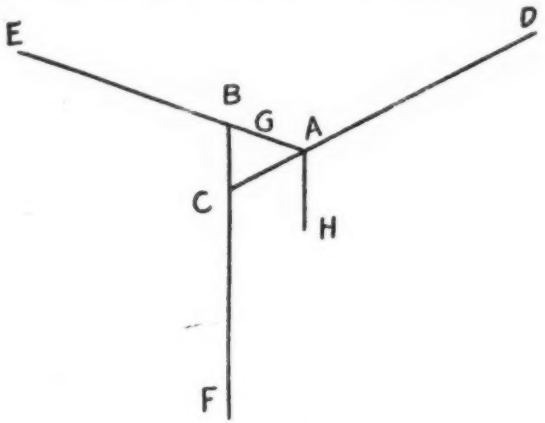


FIG. 2.

"We are told to take any triangle ABC; to produce CA to D; to make part of CD, viz., AD, revolve, about A, into the position ABE; then to make part of this line, viz., BE, revolve, about B, into the position BCF; and lastly to make part of this line, viz., CF, revolve, about C, till it lies along CD, of which it originally formed a part. We are then assured that it must have revolved through four right angles: from which it easily follows that the interior angles of the triangle are together equal to two right angles.

"The disproof of this fallacy is almost as brief and elegant as the fallacy itself. We first quote the general principle that we can not reasonably be told to make a line fulfil *two* conditions, either of which is enough by itself to fix its position: e. g., given three points X, Y, Z, we can not reasonably be told to draw a line from X which shall pass through Y *and* Z; we can make it pass through Y, but it must then take its chance of passing through Z; and *vice versa*.

"Now let us suppose that, while one part of AE, viz., BE, revolves into the position BF, another little bit of it, viz., AG, revolves, through an equal angle, into the position AH; and that, while CF revolves into the position of lying along CD, AH revolves—and here comes the fallacy.

"You must not say 'revolves through an equal angle, into the position of lying along AD,' for this would be to make AH *fulfil two conditions at once.*

"If you say that the one condition involves the other, you are virtually asserting that the lines CF, AH are equally inclined to CD—and this in *consequence* of AH having been so drawn that these same lines are equally inclined to AE.

"That is, you are asserting, 'A pair of lines which are equally inclined to a certain transversal, are so to any transversal.' [Deducible from Euc. I, 27, 28, 29]."

Thousands of mathematicians have tried in vain to prove something that only a genius could see was indemonstrable. The history of the evolution and exfoliation of that fertile idea is of very great interest to the mathematician of today, especially in view of the fact that beyond contradiction the most original researches of the last quarter of the nineteenth century pertain to the non-Euclidian geometry.

The most notable attempt to demonstrate Euclid's parallel-postulate that has been preserved to the world is embodied in a book entitled *Euclid Vindicated from every Blemish*, by a Jesuit priest named Hieronymus Saccheri (1667-1773).* He was in close association with the great Italian geometer Giovanni Ceva (through his brother Tommaso), whose name a celebrated theorem bears; and by purely geometrical methods in Euclidian style, he sought to apply the *reductio ad absurdum* method to the problem of the parallel-postulate. His method is essentially as follows: At the end-points of a sect AB erect two equal perpendiculars AC and BD on the

Euclides ab omni naevo vindicatus; sive conatus geometricus quo stabiliuntur prima ipsa universae geometriae principia.* **Auctore Hieronymo Saccherio Societatis Jesu, Mediolani.

same side of AB. Join C and D by a straight line; and it easily follows that the angle ACD is equal to the angle BDC. Now there are three possibilities: (1) The angle ACD is acute; (2) the angle ACD is obtuse; (3) the angle ACD is a right angle. He undertook to prove the absurdity of the first two possibilities so as to leave only the third possibility, viz., that the two angles ACD and BDC are each right angles. He pursued the lines of argument, following from the first two assumptions, at some length—for his book was more than a hundred pages long; but was doubtless amazed to discover that for quite a time he was unable to involve himself in any logical contradiction. In the event, certain of his conclusions were erroneous, and led him to believe that he had actually proved the parallel-postulate. What he really did do was to identify the assumption of the right angle with the parallel-postulate, thus showing the two to be mutually interchangeable postulates.

In 1766, Johann Heinrich Lambert wrote his theory of parallel lines, in which he starts from the notion of the sum of the angles of a triangle being equal to 180 degrees. If the sum is equal to 180 degrees, the triangle is a figure in a plane; if the sum is greater than 180 degrees, the triangle is on a sphere; if the sum is less than 180 degrees, the triangle is on the surface of an imaginary sphere (radius equal to the square root of minus one)—Lobatchevsky—Bolyai "imaginary geometry," so called because its trigonometric formulas are those of the spherical triangle if its sides are imaginary. As to the third hypothesis, Lambert naïvely said: "There is something attractive about this which easily suggests the wish that the third hypothesis might be true."*

France contributed little to the solution of the problem; recognition, however, should be given to Legendre, who stud-

*Compare *The Philosophical Foundations of Mathematics*, by Dr. Paul Carus; The Monist, vol. 13, pp. 273-294; 370-397; 493-522, to which I am indebted. I once had the pleasure of hearing Dr. Carus lecture on this subject before the Mathematical Club of the University of Chicago.

ied the problem all his life. By the aid of the principle of continuity, the so-called Theorem of Archimedes, he did prove two well known theorems:

1. In a triangle, the sum of the three angles can never be greater than two right angles.
2. If the sum of the three angles is equal to two right angles in one triangle, it is equal to two right angles in every triangle.

But Euclid's geometry can be built up without the continuity assumption; and only a short time ago, there was proved by Dehn, something that might have been inferred, viz., that Legendre's first theorem does not hold, i. e. not without the continuity assumption.*

In addition to Legendre, there was one other Frenchman, Joseph Lagrange, France's greatest mathematician in his day, who attempted to prove Euclid's parallel-postulate. Toward the end of his life, so the story runs, Lagrange composed a discourse on parallel lines. He began to read it in the Academy, but suddenly stopped, and, in confusion, stammered: "Il faut que j'y songe encore"—"I'll have to think about it a while longer." He stuck his manuscript in his pocket, sat down, and never recurred to the subject.

The first distinct epoch in the history of the non-Euclidian geometry begins with the time of the great German mathematician, Karl Friedrich Gauss. He is in no sense entitled to credit as a discoverer in this line, although for many years he occupied himself with the problem. The researches he claims to have made on the subject have not come down to us; but he was closely associated, according to abundant testimony, with Schweikart and Bolyai, two of the three independent discoverers of the non-Euclidian geometry. The publication in 1900 of the eighth volume of Gauss' *Collected Works* shows, from a letter to Bolyai, the elder, a Hungarian mathe-

*Compare *The Foundations of Geometry*, by David Hilbert; Translation by E. J. Townsend, Open Court Publishing Co., Chicago.

matician, that in 1779 Gauss was still hopelessly attempting to prove that Euclid's was the only non-self-contradictory system of geometry, and also the system of our space. Bolyai, the elder, submitted to Gauss, in 1804, a pseudo-proof of the parallel-postulate, but Gauss immediately detected the fallacy. When Bolyai, the elder, submitted a second pseudo-proof to Gauss, in 1808, he never replied. Bolyai's words, accompanying one of these pseudo-proofs, are pathetic in their earnestness and yearning: "Oft have I thought, gladly would I, as Jacob for Rachel, serve in order to know the parallels founded even if by another. Now just as I thought it out on Christmas night, while the Christians were celebrating the birth of the Saviour in the neighboring church, I wrote it down yesterday, and I send it to you enclosed herewith."

On November 23, 1823, Bolyai the son, called Janos, wrote a letter to his father, professor of mathematics at Maros-Vasarhely, in which he announces his discovery of the non-Euclidian geometry—a letter full of youthful fire and enthusiasm, from which I quote:

> "I intend to write, as soon as I have put it into order, and when possible to publish, a work on parallels. At this moment it is not yet finished, but the way which I have hit upon promises me with certainty the attainment of the goal, if it in general is attainable. It is not yet attained, but I have discovered such magnificent things that I myself am astounded at them.
>
> "It would be damage eternal if they were lost. When you see them, father, you yourself will acknowledge it. Now I cannot say more of them, only so much: *that from nothing I have created another wholly new world.* All that I have hitherto sent you compares to this only as a house of cards to a castle."*

His results were printed as an *Appendix* to his father's work, entitled *Tentamen Juventutem Studiosam in Elementa Matheseos Purae, Elementaris ac Sublimioris, Methodo Intuitiva, Evidentia—que huic Propria Introducendi.* The two dozen pages contributed by the younger Bolyai have been some-

**The Science Absolute of Space*, by John Bolyai, translated by G. B. Halsted; Introduction, pp. XXVII, XXVIII.

what exaggeratedly characterized as the most remarkable two dozen pages in the history of thought. When this work at last reached Gauss, he wrote to his pupil and friend, Gerling: "I hold this young geometer von Bolyai to be a genius of the first magnitude." Bolyai called his work, *The Science Absolute of Space, independent of the truth or falsity of Euclid's Axiom XI (which can never be decided* A PRIORI). And later, we read on the title page of the elder Bolyai's *Kurzer Grundriss*: "the question, *whether two straight lines, cut by a third, if the sum of the interior angles does not equal two right angles, intersect or not?* no one on the earth can answer without assuming an axiom (as Euclid the eleventh)." The work of Bolyai, the younger, which makes all preceding space only a special case, only a species under a genus, and requiring a descriptive adjective *Euclidian*, was rescued from oblivion, after thirty years, by Professor Richard Baltzer, of Dresden; and J. Hoüel, of Bordeaux, following in the steps of Baltzer, inserted extracts from Bolyai's book in his *Essai Critique sur les principes fondamentaux de la Geometrie elementaire.* Indeed, this scientist mastered the principal European languages in order to make known to his contemporaries the most celebrated mathematical works.

There is another name which deserves to become conspicuous in the history of non-Euclidian geometry; but not until 1900 were the facts in connection with his independent discovery accurately known. In a letter to the elder Bolyai, written October 31, 1851, Gerling, a scholar of Gauss and Professor of Astronomy at Marburg, wrote as follows: "We had here about this time (1819) a law professor Schweikart, who ..... had attained to similar ideas, since without help of the Euclidian axiom he developed in its beginnings a geometry which he called Astralgeometry. What he communicated to me thereon I sent to Gauss, who then informed me how much farther already had been attained on this way, and later also expressed himself about the acquisition, which is offered to the few expert judges in the Appendix to your

book." On the publication of volume 8 of Gauss's *Collected Works*, in 1900, light is at last thrown upon Schweikart's discovery. Here we find Gerling's actual letter to Gauss, written in 1819, in which he says, among other things: "Apropos of the parallel-theory, ... I learned last year that my colleague Schweikart ..... had written on parallels..... He said that he was now about convinced that without some datum the Euclidian postulate could not be proved, also that it was not improbable to him that our geometry is only a chapter of a more general geometry."* Enclosed in this letter was a paper by Schweikart, dated Marburg, December, 1818. From this we learn:

> "There is a two-fold geometry—a geometry in the narrower sense—the Euclidian, and an astral science of magnitude.
>
> "The triangles of the latter have the peculiarity, that the sum of the three angles (of a triangle) is not equal to two right angles.
>
> '*This* presumed, it can be most rigorously proven:
>
> (a) That the sum of the three angles in the triangle is *less* than two right angles;
>
> (b) That this sum becomes ever smaller, the more content the angle encloses;
>
> (c) That the altitude of an isosceles right angled triangle indeed ever increases, the more one lengthens the side; that it, however, cannot surpass a certain line, which I call the *constant.*"

It can be easily proved that if this constant is infinitely great, then, and then only, is the sum of the three angles of every triangle equal to two right angles.

That the doctrine made converts in high places is evidenced by Bessel's letter to Gauss, Feb. 10, 1829: "Through that which Lambert said, and what Schweikart disclosed orally, it

**Gauss and the non-Euclidian Geometry*, by G. B. Halsted; Science, N. S. Vol. XII, No. 309, pp. 842–846, Nov. 30, 1900.

has become clear to me that our geometry is incomplete, and should receive a correction, which is hypothetical, and if the sum of the three angles is equal to one hundred and eighty degrees, vanishes.

"That were the *true* geometry, the Euclidian, the *practical*, at least for figures on the earth."*

The third name most closely associated in the popular mind with the discovery of the non-Euclidian Geometry is that of Nicolai Ivanovich Lobatchevsky. This brilliant genius, afterwards dubbed by Hoüel the modern Euclid, was born in the year 1793 near Nijni Novgorod on the Volga. He studied under the great Bartels, was graduated with distinction, became professor of mathematics, and finally rector, of the University of Kazan. The manuscripts of certain of his works were lost, but fortunately there remains the world-famous *Geometrical Researches on the Theory of Parallels.*† While both Gauss and Lobatchevsky were students of Bartels, there is even less reason to believe that Gauss contributed to Lobatchevsky's, than that he assisted in Bolyai's, discovery of the non-Euclidian geometry. In his *New Elements of Geometry*, we find Lobatchevsky's clear enunciation:

> "The futility of the efforts which have been made since Euclid's time during the lapse of two thousand years awoke in me the suspicion that the ideas employed might not contain the truth sought to be demonstrated. When finally I had convinced myself of the correctness of my supposition I wrote a paper on it (assuming the infinity of the straight line).
>
> "It is easy to show that the straight lines making equal angles with a third never meet.
>
> "Euclid assumed inversely, that two straight lines unequally inclined to a third always meet.
>
> "To demonstrate this latter assumption, recourse has been had to many different procedures.

**The Philosophical Foundations of Mathematics*, by Paul Carus; The Monist, vol. 13. p. 280.

†Compare the English translation by G. B. Halsted, published by the University of Texas, Austin, 1891.

"All these demonstrations, some ingenious, are without exception false, defective in their foundations and without the necessary rigor of deduction."

Lobatchevsky classifies all the co-planar lines through a given point A with reference to another co-planar line BC not passing through A, under two heads—cutting and non-cutting (Fig. 3). The transition from the non-cutting lines,

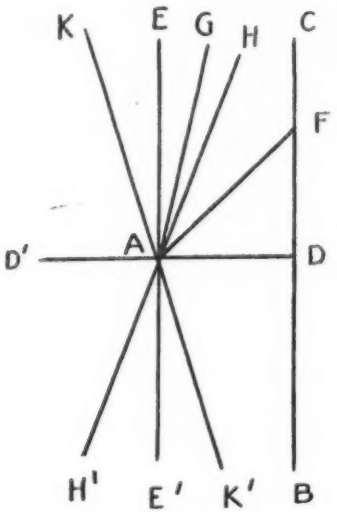


FIG 3.

such as EA and GA, to the cutting lines, such as FA, is marked by one line HA—the boundary line between the two classes; this he entitles the *parallel line*. From the assumptions, there arises the necessity of making a distinction of *sides in parallelism*, and hence there must be two parallels, so-called, one on each side. One logical consequence of this is that "if in any rectilineal triangle the sum of the three angles is equal to two right angles, this is also the case for every triangle"—one instance is the criterion for all.

As Poincaré, perhaps the world's greatest living mathematician, recently said, in his review of Hilbert's *Grundlagen der Geometrie*:

> "Lobachevski succeeded in building a logical edifice as coherent as the geometry of Euclid, but in which the famous postulate is assumed false, and in which the sum of the angles of a triangle is always less than two right angles. Riemann devised another logical system, equally free from contradiction, in which the sum is, on the other hand, always greater than two right angles. These two geometries, that of Lobachevski and that of Riemann, are what are called the *non-Euclidian Geometries*. The postulate of Euclid then cannot be demonstrated; and this impossibility is as absolutely certain as any mathematical truth whatsoever."*

Limits of space forbid more extended treatment of the work of Schweikart, of Bolyai, and of Lobatchevsky. By no means secondary in interest to the investigations of these men are the researches of Riemann upon the Elliptic Geometry; Cayley's projective theory of measurement, and the Absolute, leading through Klein to the non-Euclidian geometry; the hypotheses advanced by Clifford to explain the nature of the space in which we live; the popular expositions of Helmholtz; and Lie's great group-theoretic structure built upon the hypothesis of *Zahlenmannifaltigkeit*. Nor can I enter, at this place, into any discussion of the recent movement toward the treatment of geometry as a whole from the purely synthetic standpoint, inaugurated by Pasch, carried on by Peano, Pieri, and Veronese, and crowned by the masterly work of Hilbert. These modern investigators in what has been fittingly termed *abstract mathematics* have exhibited the potency of symbolism in removing from attention the

*Compare *The Value of Non-Euclidian Geometry*, by G. B. Halsted; Pop. Sci. Monthly, vol. 67, pp. 642-3.

concrete connotations of the ordinary terms of general and mathematical language. And yet, as Professor E. H. Moore has pertinently suggested, "the question arises whether the abstract mathematicians in making precise the metes and bounds of logic and the special deductive sciences are not losing sight of the evolutionary character of all life-processes, whether in the individual or in the race. Certainly the logicians do not consider their science as something now fixed. All science, logic and mathematics included, is a function of the epoch—all science, in its ideals as well as in its achievements..... One has then the feeling that the carrying out in an absolute sense of the program of the abstract mathematicians will be found impossible. At the same time, one recognizes the importance attaching to the effort to do precisely this thing. The requirement of rigor tends toward essential simplicity of procedure, as Hilbert has insisted in his Paris address, and the remark applies to this question of mathematical logic and its abstract expression."*

Perhaps a not unnatural confusion may arise in the mind of the layman in regard to the ultimate meaning, the far-reaching significance of these discoveries. As Artemus Ward used to say, "Why this thusness?" Indeed so revolutionary have many of the new theories and discoveries appeared that their authors, in more than one instance, have hesitated long before giving them to the world. The pioneers in science sometimes dread, not inadvisedly, the possibility that their startling and epoch-making hypotheses and investigations may lead them to be dubbed sensationalists and fakirs. Compare, for example, the letter Gauss wrote to Bessel, Jan. 27, 1829:

> "I have also in my leisure hours frequently reflected upon another problem, now of nearly forty years standing. I refer to the foundations of geometry. I do not know whether I have ever mentioned to you my views on this matter. My meditations have also taken

**On the Foundations of Mathematics*, by E. H. Moore. Presidential address, Am. Math. Soc., Dec. 29, 1902. *Science*, March 13, 1903, pp.401-416.

> more definite shape, and my conviction that we cannot thoroughly demonstrate geometry *a priori* is, if possible, more strongly confirmed than ever. But it will take a long time for me to bring myself to the point of working out and making public my *very extensive* investigations on this subject, and possibly this will not be done during my life, inasmuch as I stand in dread of the clamor of the Boeotians, which would be certain to arise if I should ever give *free* expression to my views."

As that wayward Irishman, Bernard Shaw, has said, the prime and indispensible quality of the pioneer must be his willingness to make a fool of himself—at first! And it matters not in what sphere, whether art, literature or science, the great thing, as Henrik Ibsen says, is not to allow one's self to be frightened by the venerableness of the institution.

Now that the truth in regard to many of the mooted questions which pertain to the foundations of geometry has at last been daringly disclosed, the first question that naturally arises is: Has Euclid's fame suffered by the discovery? One might be led to think so if dependence were to be placed in Clifford's characterization of Lobatchevsky's celebrated monograph as "Euclid without the vicious assumption." Such a remark is not only misleading: it displays a fundamental misapprehension in regard to the Euclidian and non-Euclidian geometries. The real truth of the matter is that Euclid's genius today shines forth more resplendently than ever; the almost flawless perfection of his work is only thrown into clearer perspective and higher relief. From the purely philosophical, the metaphysical point of view, the discovery of the non-Euclidian geometry is of vast interest; for it gives rise to endless speculations in regard to the character of space—even of inter-stellar space. Are the three angles of a triangle equal to two right angles if the sides of the triangle are the distances from the earth to the remotest fixed star? In the realization that Euclidian geometry is only a chapter in a more general geometry, fitly entitled Pan-Geometry, and the consequent almost infinite extension of the domain of research consists the great value of the discovery to the mathemati-

cian. Most interesting comparisons between the different types of geometry flow from a study of certain surfaces. Since the sum of the three angles of a spherical triangle is greater than two right angles, it is evident that the characteristic geometry of the sphere is Riemannean; it has been known, since Lobatchevsky and Bolyai, that the characteristic geometry of the orisphere is Euclidian; since Beltrami, that of the Euclidian pseudo-sphere is Lobatchevskian.* Such generalizations as Barbarin's Theorem, for example, link together the various types of geometry in a most succinct and illuminative fashion, exhibiting with great clarity their fundamental distinctions and similarities. Text books in non-Euclidian geometry are now being written; Professor Halsted entitles a popular article *The Non-Euclidian Geometry Inevitable*. The first step toward the popularization of non-Euclidian geometry is the clear enunciation, at the proper place in our ordinary text-books of geometry, of the principle on which the Euclidian geometry rests: that from the standpoint of pure logic the parallel-postulate is a mere choice between alternatives. "In all the books put into the hands of students," as M. Barbarin has said, "the hypothetical and wholly factitious character of the Euclidian postulate (should) be put well into relief."†

The second great gain from the discovery of the non-Euclidian geometry is the possibility of the formulation of the principles of the general geometry. It is most instructive and stimulating to the mathematical student to see the theories of Euclidian geometry emerge as special cases of the more general and comprehensive theories of Pan-Geometry. The

*If we consider the tubes or surfaces equidistant from a straight line, and make that distance infinite, we have the orispheres; the pseudo-spheres are surfaces of revolution which have for meridians a tractrix or line of equal tangents. A pseudo-sphere finds its approximate counterpart in nature in a morning-glory whose stem is infinitely prolonged; for a figure, cf. *Elements of Trigonometry*, by Phillips and Strong, p. 126.

†*On the Utility of Studying Non-Euclidian Geometry*, by P. Barbarin; Le Mathematiche, May, 1901.

general geometry contains many propositions common to all the systems, which should be enumerated in the same terms in each of these. Sometimes a modification in the form of statement, veiling the special property of the figure in the particular type of space, would result from a generalization of the theorems for the general geometry, in which case such special properties should be clearly indicated. Thus, to state an illustration cited by M. Barbarin,* that of the convex quadrilateral inscribed in a circle, in Euclidian geometry, *the sum of two opposite angles is constant and equal to two right angles*; in non-Euclidian geometry, *this sum is variable.* Notwithstanding this, the two forms may be reconciled, since in both cases *the sum of two opposite angles equals that of the other two*, and this is sufficient for a convex quadrilateral to be inscriptible. Such generalizations often lead to a complete redistribution of values, and so clarify the processes of Euclidian geometry in the most distinctive way. Professor E. Study has said:

> "The conception of geometry as an experimental science is only one among many possible, and the standpoint of the empiric is as regards geometry by no means the richest in outlook. For he will not, in his one-sidedness, justly appreciate the fact that in manifold, and often surprising ways the mathematical sciences are intertwined with one another, that in truth they form an indivisible whole.
>
> "Although it is possible and indeed highly desirable that each separate part or theory be developed independently from the others and with the instrumentalities peculiar to it, yet whoever should disregard the manifold interdependence of the different parts, would deprive himself of one of the most powerful instruments of research.
>
> "This truth, really self-evident yet often not taken to heart, applied to Euclidian and non-Euclidian geometry, leads to the somewhat paradoxical result that, among conditions to a more profound understanding of even elementary parts of the Euclidian geometry, the knowledge of the non-Euclidian geometry cannot be dispensed with."†

**On the Utility of Studying non-Euclidian Geometry*, l. c.

†*Ueber Nicht-Euklidische und Linien-Geometrie*, Greifswald, 1900.

Lastly, the discovery of the non-Euclidian geometry virtually fixes upon the Euclidian geometry its practical and empirical character. "In connecting a geometry with experience," to cite the view of the most confirmed of non-Euclidians, "there is involved a process which we find in the theoretical handling of any empirical data, and which therefore should be familiarly intelligible to any scientist. The results of any observations hold good, are valid, always only within definite limits of exactitude and under particular conditions. When we set up the axioms, we put in place of these results statements of absolute precision and generality. In this idealization of the empirical data our addition is at first only restricted in its arbitrariness in so much as it must seem to approximate, must apparently fit, the supposed facts of experience, and, on the other hand, must introduce no logical contradiction. Thus to-day the ordinary triply-extended space of our experience may be purely Bolyaian, or purely Euclidian, or purely Cliffordian, or purely Riemannian."* To put it extravagantly, the non-Euclidian geometer, like a croupier, cries out to his audience: "Here are three assumptions in regard to the angle sum of a triangle; from not one of the three do any logical contradictions follow; which one will you take? *Messieurs, faites vos jeux!*" The result is, not that the mathematical world singles out one to the exclusion of the others—but studies all three, their inter-actions, inter-relations, and mutual dependencies. And yet if the "man in the street" impatiently cries out: "I am not interested in what may be the possible nature of space in the vicinity of Mars, or even the possible character of geometrical figures on the planet Jupiter, or in the tortuous reasonings of a mathematical Alice in Wonderland. Tell me, what is the character of the space I occupy, the nature of the physical world in which I live and move and have my being?" And the answer of mathematicians throughout the world, with certain distinguished exceptions,

**The Appreciation of non-Euclidian Geometry*, by G. B. Halsted; *Science*, March 22, 1901, pp. 462-465.

would doubtless be: "Although it can never be mathematically demonstrated, our space I believe to be Euclidian space because of the testimony of experience." The three angles of a triangle can never be mathematically demonstrated to be equal to two right angles; nor can experience ever give the absolutely exact metric results desiderated. And yet, this thing amounts to what we crudely call "moral certainty", viz. that the "practical geometry", as Bessel rightly called it, within reasonable limits of error—for which we must always allow in this imperfect world—, and for limited portions of space, is Euclidian. So, after all, it seems that we are forced to the conclusion that the axioms of geometry, although they are, abstractly speaking, assumptions, are, practically speaking, deductions from experience. Only as suppliants at the feet of Nature herself can we ever hope to penetrate to the heart of her mystery.

A NEW COLOR TEST FOR THE LIGNOCELLULOSES.

ALVIN S. WHEELER.

The lignocelluloses give a number of color reactions, the most valuable being the reaction with phloroglucinol in hydrochloric acid solution. The rich reddish violet color is very pronounced. The salts of anilin give a golden yellow but the color is not sufficiently dark to allow them to compete with phloroglucinol. However, I have observed that the salts of the nitranilines produce a color which is very striking, a rich blood red color. As phloroglucinol solutions are said to deteriorate with age, I have kept for one year exposed to full daylight a hydrochloric acid solution of phloroglucinol and also one of paranitraniline. The phenol solution became brown, showing some decomposition and on applying it to pine sawdust the violet color was not fully developed instantly but in a few minutes became as dark as that made by a fresh solution. The nitraniline solution was perfectly stable and gave its reaction as quickly as a fresh solution. So far as a year's time is concerned the new reagent has no real advantage over the old.

The red color is produced by the salts of the ortho, meta and paranitranilines but the meta compounds are much inferior, the color being pale in comparison. The ortho and para compounds give the same deep color. Paranitraniline is to be preferred since it is more readily obtained. Different salts of this amine such as sulphate, nitrate, hydrobromide and hydrochloride were tested but no difference was noted. The hydrochloride was adopted for use. This salt, dissolved in pure water, only gives a yellow color, but on stand-

ing for some hours the red color develops. Since the best results are obtained when free acid is present, various strengths of hydrochloric acid were tried from one-half to a twelve per cent. solution but no important difference could be observed. It is convenient to use an acid of specific gravity 1.06. A study of various concentrations of the paranitraniline in acid solution revealed no differences of consequence. It was observed that in all cases hot solutions produced much quicker results than cold ones. In fact hot solutions seemed to give the full depth of color instantaneously.

The reagent was applied to a wide variety of woods, to jute, to oat straw and to many samples of paper. A No. 1 book paper showed numerous small red fibres, indicating adulteration with mechanical wood or else incomplete conversion of the lignocellulose. A yellow paper containing five per cent. of mechanical wood gave a deeper color, likewise a salmon pink paper. A very deep blue paper made of sulphite cellulose showed scattering red fibres which were easily seen. A sample of white paper made from bleached sulphite gave no trace of color.

A striking lecture experiment is carried out by projecting a quantity of the hot solution against a large sheet of paper made of mechanical wood, such as newspaper stock.

In conclusion, the reagent is made by dissolving two grams of paranitraniline in one hundred cubic centimeters of hydrochloric acid, either of specific gravity 1.06 or a 4N solution. When used hot, a blood red color is instantaneously obtained with lignocelluloses.

University of North Carolina,
February 21, 1907.

NOTES ON THE GEOLOGY OF CORE BANK, N. C.

BY COLLIER COBB.

The storm of October 17th, 1906, cut three inlets across Core Bank, just below Cedar Island Inlet (closed since 1805) and near the site of Old Drum Inlet (closed in 1822), and revealed the fact that the beach sands and dunes (Columbia) rest upon a clay foundation (Neocene), which in its turn is underlaid by Tertiary shell-rock, exactly similar to the shell rock occurring at various points in Currituck Sound and already noted in this Journal.* Among the forms observed here were *Turritella*, *Lunatia*, *Glycymeris*, *Tornatellaea*, *Nucula*, *Lucina*, *Corbula*, *Protocardia*, *Modiolus*, *Arca*, *Ostrea*. These were in most cases packed together in the shell-rock, and a few sharks' teeth were included. The upper portion of this rock was made up almost entirely of the shells of *Tellina*. After the storm the entire bank in the region of the new-formed inlets was black with magnetic sands, heavily ripped, their thicknes being in some cases as much as three inches.

Numerous water-worn shells of *Cardium*, *Anomia*, *Exogyra*, *Serpula*, *Gryphaea*, of species identical with those found by the writer on Currituck Banks, were washed up by the storm, as were also the bones of fishes, all these being Cretaceous fossils. Many coral fragments were also found. The Captain of the Core Bank Life Saving Station, Willis, sailed through one of the inlets and found six feet of water in its shallowest part. On December 16th, 1906, I walked across all three of the inlets at low water in company with Captain Wm. T. Willis of the Core Bank Life Saving Station,

*Vol. xxii, No. 1, 1906, pp 17-19.

and Mr. R. C. Holton of Atlantic, the washing up of sand from the sea and the southward movement of the dunes having nearly filled them.

The Tertiary shell-rock was encountered in Core Sound between Core Bank and Cedar Island, and between Core Bank and the mainland. There is thus no longer any question as to the origin of Core Bank or of Currituck Bank, for they are both essentially parts of the mainland. Currituck Sound was formerly a river that flowed into the Albemarle or Caroline River before the present Albemarle Sound was formed by the drowning of that valley; and Core Sound was for the greater part of its length a southern tributary of the large river made up of the Pamlico and the Neuse, and passing to seaward through the present Ocracoke Inlet. The Albemarle River passed through the present fresh ponds just south of the Kill Devil Hills, and the margin of the continent was some three score miles eastward of its present position.

Then came the subsidence which drowned out the lower river valleys producing the estuaries and sounds already mentioned, and this subsidence may still be in progress in the region to the north of Cape Hatteras.

Since that subsidence, however, there has been an uplift of the land from Cape Hatteras southward, which, in all probability is still going on. As the dunes advance towards the sound side they depress by their weight the swamp muck in which the trees of that side grow, and these are left exposed on the seaward side when the dunes have passed. This compression of the muck, which is common from Hatteras Island northward, may easily be mistaken for subsidence of the land.

But on the land opposite Core Bank, successive strata of muck, filled with well-rounded wind-blown sands rise twenty feet above Core Sound at Atlantic. Kitchen middens, too, mark this line of elevated shore, the heaps being composed mainly of oyster shells with an occasional bit of broken

Indian pottery, and an occasional stone cleaver. Similar evidences of recent elevation have been observed by the writer at various points from Cape Hatteras to Cape Sable.

NOTE—This paper was presented, with lantern illustrations, before Section E, of the American Association for the Advancement of Science, New York, December 31st, 1906, and an abstract appears in *Science* N. S. vol. xxv, p. 297, Feb. 22, 1907.

NOTE ON ELECTRICAL AGEING OF FLOUR.

J. W. GORE.

The Alsop Process of Ageing flour was described in the Electrical World of December 8th, 1906, which is now in use in many mills in the United States and also in foreign countries.

The apparatus consists of a 500 volt Shunt Wound dynamo, with an induction coil in series with it, and an air pump.

The circuit is automatically broken at each stroke of the pump; the break is between two copper electrodes, and the resulting arc is drawn out until broken.

The air through which this flaming Electrical discharge passes is forced by the air pump through the flour as it comes from the mill.

A 1½ kw dynamo is sufficient for a mill of some 30 to 40 barrels daily output.

It has been the practice of millers and warehouse men for a long time to age fresh flour by storage, thus fitting it better for bread and yielding a higher grade product. By Alsop's process these beneficial results are obtained in a few moments.

The conclusion is that the active elements in the atmosphere which improve the bread making qualities of the flour when stored, are plentifully produced by the flaming discharge of Electricity between Copper Electrodes.

INDUSTRIAL AND SCIENTIFIC ASPECTS OF THE PINE AND ITS PRODUCTS.*

BY CHAS. H. HERTY, PH.D.

Consideration of the annual production of volatile oils shows at once the great preponderance of spirits of turpentine over all others combined. Each quart of spirits of turpentine represents approximately one year's output of this product from one tree. At least nine-tenths of the world's supply of this substance comes from our Southern States, for the production of which not less than one hundred and twenty millions of trees are annually subjected to turpentining. Two millions of acres of virgin timber are annually brought into operation to supply the place of exhausted timber. Millions of pines which have never been turpentined are felled each year by the mills in Mississippi, Louisiana and Texas. Every winter the entire turpentine producing section is swept by ground fires which destroy most of the seedlings, and thus make impossible reproduction on any large scale. The annual revenue from the naval stores industry can be conservately estimated under present prices at not less than forty millions of dollars. Surely such a situation justifies and demands systematic experimental work in the hope of conserving this valuable native resource.

EFFECT OF TURPENTINING ON LUMBER.

The pine has a two-fold commercial value, first, as timber, second, as a producer of the oleo-resin, "crude turpentine."

*Reprinted from *The Chemical Engineer*, March, 1907.

For many years it was believed that timber which had been turpentined, commonly called "bled timber," was inferior to "unbled" for construction purposes. A thorough investigation of this question in 1893 by the Division of Forestry of the U. S. Department of Agriculture showed the fallacy of this belief, and now no distinction is made. Indeed in France timber from trees which have been turpentined is preferred for all purposes where strength and elasticity are demanded.

CRUDE TURPENTINE.

Previous to the last twelve years no systematic experiments had been carried out in this country on the production of crude turpentine. The records of the U. S. Patent Office as far back as 1869 show various inventions designed as substitutes for the "box," this being a deep hole cut in the base of the tree, having a capacity of about one quart and serving to collect the crude turpentine which flows from the scarified trunk above. None of these devices however gained permanent favor among turpentine operators. In 1894 W. W. Ashe, of the N. C. Geological Survey, began a comparative study of crude turpentine collected by the "box" system, uniformly practiced in this country, and by the "cup" or Hugues system, practiced in France. These experiments were planned with care, and although carried out on a small scale gave interesting results. They were discontinued after one year.

In the hope of accomplishing something toward the conservation of the pine forests of Georgia I began during the summer of 1901 field experiments on the production of crude turpentine by the pine. With an apparatus somewhat similar to that used in France, but essentially modified to suit our system of scarification or "chipping," various studies, both qualitative and quantitative, were made in the pine forests of the southern part of the State. Many of the specimens collected were afterwards examined in the chemical laboratory. The striking character of the results obtained aroused the interest of the U. S. Bureau of Forestry, and during the fol-

lowing winter I was led to accept a commission in the Bureau for the purpose of carrying out on a commercial scale the experiments already begun.

As introductory to the discussion of that work let me explain briefly the operations commonly in practice in the turpentine woods. During the winter the "boxes" are cut in the trees. In early spring the weekly scarification or "chipping" begins. It is necessary to renew this wound each week, as the flow of crude turpentine practically ceases after seven days. Chipping extends each year about eighteen inches up the tree, the depth of the cut being about one inch and the width, on an average tree, fourteen inches. When the boxes fill, usually every four or five weeks, the crude turpentine is removed to buckets, then to barrels and hauled to the still. During the year some of the product remains sticking to the exposed "face" of the tree. This is collected in the fall and distilled, although it has a much smaller percentage of spirits of turpentine than the "dip" from the boxes. Lastly a space around each tree is cleared of all combustible material as a protection against the annual ground fires.

The basis of my work was the conviction that the pine is not so much a store-house but rather a factory for the production of crude turpentine, and that timber which is not boxed should produce more than timber whose vitality is diminished by the cutting of the box. Comparative experiments were carried out in 1903 at Ocilla, Ga., on thirty thousand trees. In these experiments both the "box" and the "cup and gutter" systems were used under conditions as nearly identical as possible. The results showed an even greater difference in favor of the unboxed timber than was expected, while the qualitative results previously obtained by Ashe were confirmed. The immediate commercial introduction of the cup and gutter system was assured by the financial gain from the increased output, the improved quality of the rosin and the protection given to the trees against wind and fire.

For the production of crude turpentine it is necessary to

wound the tree. If the tree is girdled it dies. What then is the limit of wounding to which it is necessary to subject the tree in order to get the most profitable yield, and beyond which it is unsafe to go? It had been proved at Ocilla that the box was an unnecessary wound and that by its elimination the yield could be increased. The next step then was to make comparative tests bearing upon the extent of the wound given in "chipping." For the past two years such experiments have been conducted in Florida by the U. S. Forest Service, and by the courtesy of the Service I am enabled to tell you that results already obtained show that shallow chipping produces as much or eventually more crude turpentine than the customary deep chipping, while at least one year in three can be gained in the usual rate of ascent of the tree without diminishing the output. Still other experiments yielding most valuable results are in progress, all bearing upon more conservative wounding of the tree. None of these experiments are extreme, but all are rational modifications of present practices which will carry conviction when the details are published.

Of an entirely different character from the experiments just mentioned, but of great scientific and practical value, are the recent studies of Prof. A. Tschirch, of Switzerland, on resin secretion. By the use of the microscope and suitable stains he has proven that the seat of resin production is in a mucilaginous layer lining the inner walls of the resin ducts. In a later study, carried out upon a large number of trees, he has further demonstrated that while there are a limited number of "primary" resin ducts present in the untapped pine, by far the greater flow of resin proceeds from secondary ducts formed in the outer sap wood after the wounding of the tree. The resin from the "primary" ducts is a physiological product, that from the "secondary" a true pathological product.

While many chemical studies have been made of the products obtained by distillation of crude turpentine, only one detailed investigation is on record regarding the nature of the

oleo-resin secreted in the Longleaf pine. Tschirch and Koritzschoner have shown that this oleo-resin consists of

Palabienic Acid—$C_{13}H_{20}O_2$	5 per cent.
Palabietic Acid—$C_{20}H_{30}O_2$—	6 " "
α and β—Palabietiolic Acid—$C_{15}H_{24}O_2$—	56 " "
Spirits of Turpentine	20 " "
Paloresene	10 " "
Impurities, Bitter Principle and Water	3 " "

No study has been published of the oleo-resin from Pinus Heterophylla, or Cuban pine, which occurs so frequently in the Florida forests and from which therefore so large a proportion of the present supply of spirits of turpentine and rosin is prepared. Such an investigation has been begun in the laboratory of the University of North Carolina.

Many interesting new lines of investigation in this field suggest themselves if the chemist instead of waiting for specimens to reach the laboratory will study and note the changes at the tree. When the oleo-resin first appears it is a perfectly clear liquid. In the case of some pines it remains thus for weeks and then slow crystallization of the dissolved acids begins, with others the crystallization begins within a minute after the drop appears. Evidence already in hand points to the probability that the clear liquid issuing from the resin ducts is a supersaturated solution. To what is this condition of supersaturation to be ascribed? Again, the flow of resin is relatively rapid during the first forty-eight hours after wounding, then quickly diminishes and practically ceases after seven days. Is this cessation to be explained by the plant physiologist or by the chemist? Has the inner lining of the resin duct lost its power of production, or has the duct been closed by oxidation, or crystallization of the oleo-resin which it exudes? If chemical, can it be prevented by some simple means? A practical solution of this problem would be a great blessing to the turpentine operator in these days of scarcity of labor and would do more than anything

else for the preservation of our pine forests. Still again—what is the chemistry of "scrape" formation? Why the variation in the amount of scrape formed in pines of different species and even among those of the same species? These are a few of the many problems in this untouched field awaiting the skill and patience of the investigator.

DISTILLATION.

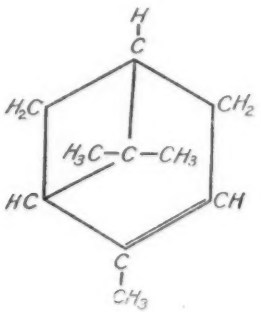
Crude turpentine is of very little commercial use. It must be separated by distillation into its constituents, spirits of turpentine and rosin. In this country distillation is carried out in large copper stills heated by direct fire. During distillation a current of warm water is let into the still. The steam produced by the water added during distillation materially lowers the temperature and lessons the time necessary for the complete removal of the spirits of turpentine. An interesting study of this subject from a physico-chemical standpoint has been made by Prof. Vezes, of Bordeaux. By distilling at this lower temperature the possibility of destructive distillation of the rosin is avoided. The vaporized spirits of turpentine and the steam are condensed in a water jacketed copper coil and collected in a suitable vessel where separation takes place owing to the difference in specific gravities and the mutual insolubility of the two liquids. On completion of the distillation the cap of the still is removed and the excess of water boiled off to prevent opaqueness in the rosin. The molten rosin is then run through an opening near the bottom of the still into strainers lined with cotton batting through which it filters into a vat. After partial cooling the rosin is dipped into barrels where it slowly solidifies.

During the summer of 1903 I had opportunity to study the systems of distillation practiced in France. Three types were found, first distillation by free flame and addition of water, as in this country, second by steam alone in steam jacketed stills, and third by a system of "mixed injection," i. e. free

flame and addition of water together with steam injection. The cost of a plant for distillation by steam alone is far greater than that of the simple plants in this country. After careful study of these systems I am convinced that if a skillfull "stiller" is in charge, as good results are obtained here as with the best of the French steam stills, but the personal equation, which plays no role in the steam still, is of prime importance with us. Perhaps the best of these for our conditions would be that of mixed injection, for the extra cost of installation and operation is not great and the personal element of the "stiller" is entirely eliminated.

SPIRITS OF TURPENTINE.

The chief constituent of spirits of turpentine is pinene, $C_{10}H_{16}$. Many battles have been waged over the structural formula of this compound. At first it was classified among the open chain hydrocarbons but later was shown to be a ring compound. Of the many formulas proposed that of Wagner is most in accord with the reactions of the substance.



Some of the work upon American spirits of turpentine has been in vain, because investigators failed to take into account the facts that in our turpentine orchards more than one species of pine is turpentined and that the crude turpentine from each is indiscriminately mixed when collected. Recognizing these

facts J. H. Long in 1893 secured specimens from identified individual trees, distilled the volatile oils from each and concluded that while American turpentine rotates the plane of polarized light to the right the variations in the amount of rotation in different specimens is due to admixture of the lævo-rotatory oil from Cuban pine with the dextro-rotatory oil from the Long leaf pine, and as the latter tree generally predominates the resultant oils are more or less dextro-rotatory. New light has been thrown upon this subject by an investigation carried on during the past year in the chemical laboratory of the University of North Carolina in collaboration with the U. S. Forest Service, by which the results of this study are to be published shortly. Through the courtesy of the Service I am enabled to refer to some of the results of special interest in this connection. During the past season, at regular intervals of four weeks, the crude turpentine has been collected separately from seven Longleaf and seven Cuban pines. A study of the oils distilled from these specimens has shown a marked variation in the rotation of polarized light. The variation exhibits itself not only in the oils from the two species of pines, but even among those from the same species. The Longleaf pines generally yielded dextro-rotatory oils. One, however, yielded a lævo-rotatory oil, while another scarcely affected the plane of polarization. The Cuban pines gave generally lævo-rotatory oils but through wide variations, one of them effecting only a very slight rotation. In the case of each tree, however, the rotation of its oil was found to be practically constant throughout the season.

The rapid rise in the price of spirits of turpentine during the past few years has led to frequent adulteration and the offering for sale of many substitutes. The producer, tempted by the great difference in price of spirits of turpentine and kerosene, has frequently mixed the two. The remedy was peculiar. Seeking to advance the price by producing less spirits of turpentine, the operators soon found that their successful effort to curtail had been fully off-set by the addition,

at many stills, of kerosene sufficient to keep the output at its former figures. The most prominent producers then led the fight for "pure spirits" laws and in the largest producing States effective legislation on this subject has been enacted. Similar laws have recently been passed in New York State.

Mineral oil constitutes the chief adulterant of spirits of turpentine. While such an addition may not materially lower the solvent power, it diminishes the oxygen carrying power directly in proportion to the amount present, since American petroleum is composed almost wholly of saturated hydrocarbons. So skillful has become the art of adulterating with petroleum products that detection by the ordinary physical tests can be evaded if the adulterant is not present in too great quantity. But by polymerization of the terpenes with concentrated sulphuric acid, Herzfeld's method, adulterations even as low as one to two per cent. can be detected with certainty. Especially is this true if after successive polymerizations the oils, distilled with steam, be examined with the refractometer, as recommended by McCandless.

No discussion of spirits of turpentine would be complete without embracing that form now legally designated as "wood spirits of turpentine." It is no new thing that a volatile oil, various heavy oils and charcoal can be obtained by destructive distillation of "fat lightwood." More than forty years ago extensive plants for such distillation were in operation in North Carolina. But the low price of spirits of turpentine made these financial ventures unsuccessful. A few plants continued operations on a small scale, but the matter dropped out of public notice for a long while. With the recent rise in price the subject was again agitated. By the aid of clever promotion, by the exhibition of actual results obtained, but from raw material above average richness, by frequent reference to latter-day success in saving and utilizing by-products and finally by that sweet vision of pestiferous stumps removed from the cotton rows, great enthusiasm was raised, and at one time unlimited capital was available for destructive dis-

tillation plants, provincially called "stump factories." Many were built, but it was soon found that the paint and varnish people did not want the product, as the quality was irregular and the odor bad. Then, too, the by-products so carefully saved found no market. Finally through faulty construction or careless management many of the plants burned. Consequently destructive distillation lost favor and plants were erected for the extraction from lightwood by steam of spirits of turpentine alone. This method gives an oil of good quality, and with increased experience a product is now manufactured which is practically the same as "gum spirits." But the yield from average raw material is rather low and if it be sought to increase the yield by elevation of temperature the quality is inferior.

I think I have stated the case fairly. We all hope that this industry will eventually be placed upon a good solid basis. Let me emphasize three points in connection with this subject:—

First.—Fewer promoters and more chemists would improve the situation.

Second.—Investors must not expect to realize the enormous profits claimed by some of the over-enthusiastic, but the business is capable of yielding fair dividends if the plants are properly located and carefully managed.

Third.—In spite of the preference now shown for steam extraction, the future of this industry lies in destructive distillation, but not as at present practiced. The difficulty of securing profitably a permanent supply of raw material will lead to the establishment of numbers of cheap stills. Such stills require no expert labor and can be easily moved from time to time to fresh portions of the territory for raw material. The crude product from these small stills will be shipped to central refineries where suitable apparatus will be found operated under the direction of chemists.

ROSIN.

What is rosin and of what chemical compounds is it

composed? This question has interested chemists for many years. The literature of the subject is very extensive and the views held at various times were and even now are widely different. By Maly and Flückiger rosin was considered the anhydride of abietic acid. Henriques contended for the presence of lactonic acids, Benedict for free acids and ethereal salts, Fahrion for sylvic acid, while Tschirch has recently separated from American rosin three isomeric acids α, β and γ abietic acids, and considers that all other workers in this field have been dealing with impure products. The controversy on this subject between Tschirch and Fahrion is not yet ended. Tschirch can not decide between $C_{19}H_{28}O_2$ and $C_{20}H_{30}O_2$ as the correct formula for abietic acid. Nor has it been determined with any certainty whether the oxygen atoms of this acid are present in the form of hydroxyl or carboxyl groups. It is possible that some of these differences may be due to the fact that many of the specimens used for investigations are so called "American Rosins," without taking into account the fact that much of this rosin is derived from at least two different species of pines, Pinus Palustris and Pinus Heterophylla.

Rosin varies in color from a pale yellow to a very deep red, the price of the rosin decreasing with increasing color. In France the better grades of rosin are placed in shallow trays and exposed for three or four months to the bleaching action of sunlight. Almost colorless grades are thereby obtained. This practice is carried on by one firm in this country. But sun-bleaching is not effective with the darker rosins. The great difference in price between the low and high grades has led to many efforts to devise chemical methods for bleaching rosin. A number of patents have been issued on the subject, but so far as I know none of these have proved commercially profitable. Here is a live problem for the chemist, the correct solution of which is certain to bring rich returns.

For many years the commercial demand for rosin was very

limited. Indeed at one time the price dropped so low that it was frequently the custom in North Carolina to distill the oil from the crude turpentine and turn the rosin into the creeks and swamps. In these latter days of higher prices the rosin from these dumping grounds has been dug up, melted, strained and shipped to market. The cause of this increase in price is not difficult to discover. It is the manufacture of rosin oil. Of the total amount of rosin produced about 10 per cent. is used for sizing, varnishes and other minor matters, 35 per cent , approximately, for soap making, while not less than 55 per cent. is subjected to destructive distillation whereby rosin spirits, various rosin oils, brewers pitch, etc., are obtained. As a substitute for or adulterant in linseed oil, as lubricants, in printer's ink and in many other ways rosin oils are finding wider and wider application. This industry thrives chiefly in Germany, to quite a large extent in England and Scotland, and a much more limited extent in France, where a high tariff prevents the importation of American rosin. In this country there are about three rosin oil distilleries, operated somewhat in the same manner as the European plants. Why should not this industry thrive in our Southern States? It would seem that the same logic which led to the recent movement to erect cotton mills near the fields of cotton would apply in this case also. We have a great advantage over the foreign manufacturer if we will only make use of it. When the German or English rosin oil manufacturer gets the rosin thoroughly melted in his still he is just at the point where we were at the moment the molten rosin was turned out of our turpentine still into the vat. Meanwhile what has happened? The heat stored up in the molten rosin has gone to waste, there has been added the labor of dipping it from the vat into the barrels, the cost of inspection, broker's commissions, transportation costs, labor in getting the rosin from the barrels and breaking it into lumps of suitable size for the still, and finally the cost of fuel for again melting the rosin, and why? All in order to get it

back again into the condition in which we once had it. Many industries have been developed on a much narrower basis of saving than that just indicated. Adjacent to each of our turpentine stills there should be found one or more for rosin oil, placed on a lower level, so that the molten rosin could be run directly from the one to the other and destructive distillation of the rosin begun. The stills for rosin oil being made of iron are not expensive and the skill required for distilling is far less than in the distillation of crude turpentine. Again, but little labor would be required, nor would it be necessary to find markets or uses for the products: these already exist and are constantly increasing. With such manifest advantage we should be able to locate the whole of this industry in our midst.